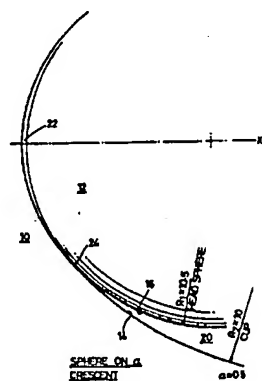
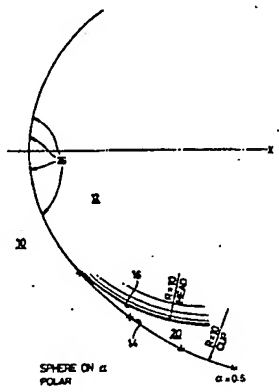


PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION  
International Bureau



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<p>(51) International Patent Classification <sup>6</sup> : A61F 2/34</p>	<p>A1</p>	<p>(11) International Publication Number: WO 95/23566 (43) International Publication Date: 8 September 1995 (08.09.95)</p>
<p>(21) International Application Number: PCT/GB95/00403 (22) International Filing Date: 27 February 1995 (27.02.95) (30) Priority Data: 9404077.1 3 March 1994 (03.03.94) GB (71) Applicant (for all designated States except US): UNIVERSITY OF LEEDS [GB/GB]; Leed, West Yorkshire LS2 9JT (GB). (72) Inventor; and (75) Inventor/Applicant (for US only): FISHER, John [GB/GB]; The department of Mechanical Engineering, University of Leeds, Leeds, West Yorkshire LS2 9JT (GB). (74) Agent: TUNSTALL, Christopher, Stephen; Dibb Lupton Broomhead, 117 The Headrow, Leeds, West Yorkshire LS1 5JX (GB).</p>		<p>(81) Designated States: JP, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  Published With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</p>
<p>(54) Title: ACETABULAR CUP</p> <p>(57) Abstract</p> <p>A prosthetic joint is described consisting of an acetabular cup (10) and a femoral component having a spherical head (12) of radius <math>R_1</math>. The surface (14) of the socket in the acetabular cup (10) is defined by an "alpharabola". The alpharabola geometry is described by: <math>\alpha x^2 + y^2 + z^2 = 2R_2x</math>, <math>0 &lt; \alpha &lt; 1</math>, where <math>R_2</math> is the desired minimum radius of curvature; <math>x</math> is a Cartesian coordinate representing distance from the point of minimum radius of curvature (30) along the normal to the surface at that point; and <math>y</math> and <math>z</math> are the remaining Cartesian coordinates. The alpharabola surfaces are surfaces of revolution about the <math>x</math> axis. When <math>R_2</math> is less than <math>R_1</math>, a pool of fluid (22) is trapped at the pole of the apharabola and there is an annular contact ring (24) between the two surfaces (14, 16) which serves to trap the fluid. When <math>R_1</math> is equal to <math>R_2</math>, in place of an annular contact ring (24), there is an enlarged contact area (26). Both arrangements contribute to more effective squeeze film lubrication and less wear on the two components (10, 12).</p> <div style="text-align: right;">   </div>		

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	GB	United Kingdom	MR	Mauritania
AU	Australia	GE	Georgia	MW	Malawi
BB	Barbados	GN	Guinea	NE	Niger
BE	Belgium	GR	Greece	NL	Netherlands
BF	Burkina Faso	HU	Hungary	NO	Norway
BG	Bulgaria	IE	Ireland	NZ	New Zealand
BJ	Benin	IT	Italy	PL	Poland
BR	Brazil	JP	Japan	PT	Portugal
BY	Belarus	KE	Kenya	RO	Romania
CA	Canada	KG	Kyrgyzstan	RU	Russian Federation
CF	Central African Republic	KP	Democratic People's Republic of Korea	SD	Sudan
CG	Congo	KR	Republic of Korea	SE	Sweden
CH	Switzerland	KZ	Kazakhstan	SI	Slovenia
CI	Côte d'Ivoire	LI	Liechtenstein	SK	Slovakia
CM	Cameroon	LK	Sri Lanka	SN	Senegal
CN	China	LU	Luxembourg	TD	Chad
CS	Czechoslovakia	LV	Latvia	TG	Togo
CZ	Czech Republic	MC	Monaco	TJ	Tajikistan
DE	Germany	MD	Republic of Moldova	TT	Trinidad and Tobago
DK	Denmark	MG	Madagascar	UA	Ukraine
ES	Spain	ML	Mali	US	United States of America
FI	Finland	MN	Mongolia	UZ	Uzbekistan
FR	France			VN	Viet Nam
GA	Gabon				

## ACETABULAR CUP

This invention relates to an acetabular cup and to a prosthetic hip joint consisting of the acetabular cup and a femoral component. In particular, the invention relates to such a joint having improved lubrication qualities.

5

Background to the invention

Over half a million artificial hip joints are implanted in patients every year. These are all ball and socket joints with a spherical femoral head and a hemispherical acetabular cup or socket. Over 95% of these comprise a hard metal or ceramic head, with an ultra-high molecular weight polyethylene cup. Other types include metal on metal and ceramic on ceramic and, more recently, soft or compliant bearing surfaces, termed "cushion form bearings". All these joints have a primarily spherical geometry with the radius of curvature of the head  $R_1$  being smaller than the radius of curvature of the socket  $R_2$ . This allows the joint to be assembled and free to move. Typically, the radial clearance  $R_2 - R_1$  is between 0.05 and 0.5mm. The smaller radial clearances are used for hard on hard prostheses, such as metal on metal and ceramic on ceramic, with larger clearances being used for cushion form bearings. For commonly used polyethylene  $R_1 - R_2$  is between 0.01 and 0.03mm. Typically, when the two spheres come into contact at a point the materials then deform elastically with the contact area increasing as the load and contact stress increase. The radial clearance and the elasticity of the materials determine the contact area, stress and lubricating film thickness, all of which determine the wear of the materials.

30

In hard on hard and cushion form bearings, there are real concerns about high levels of friction at start up after periods of high constant load when the lubricating film has been squeezed out from between the two joint components. It has been proposed in metal on metal joints to form a dimple or local discontinuity in the surface of the cup at the pole,

35

in an attempt to trap the fluid and reduce friction. It is not clear whether this works, but it has been established that the dimple produces discontinuities in the stress field.

- 5 It is an object of this invention to provide a prosthetic hip joint with improved lubrication and reduced wear.

#### Summary of the invention

- According to the present invention, there is provided an  
10 acetabular cup having a concave bearing socket adapted to receive the head of the femoral component of a hip prosthesis, in which the radius of curvature of the surface of the socket continuously and monotonically decreases from the lip of the socket to a minimum  $R_2$  at a point within the socket. The  
15 acetabular cup according to the invention provides distinct advantages when used in conjunction with a standard femoral component having a substantially spherical head when  $R_2$  is no greater than the radius of the spherical head of the femoral component  $R_1$ . When  $R_2$  is equal to  $R_1$ , there is no single point  
20 of contact between the spherical head and the acetabular cup, but rather an enlarged contact area through which more uniform pressure is applied under load. Furthermore, since towards the lip of the socket the radius of curvature increases - and hence the amount of curvature decreases - a larger space is  
25 defined between the socket and the head than would be the case with two spherical components.

- When  $R_1$  is greater than  $R_2$ , the bearing still fits together by virtue of this continuous monotonic increase in the radius of  
30 curvature as the lip of the socket is approached, but importantly a pool of lubricating fluid is trapped at the pole of the socket. Both these arrangements contribute to more effective "squeeze film lubrication" which occurs when load is applied to the joint and a film of lubricating fluid is  
35 squeezed between the two components. They also both act to spread the applied load more effectively over the surfaces of the components, either over a large contact area towards the pole or over a contact area spaced from and distributed around the pole.

Preferably, the surface of the socket approximates that of a sphere at the point of minimum radius of curvature. In these circumstances, it is preferred that  $R_2$  is equal to  $R_1$ . This ensures that there is a large contact area between the femoral head and the acetabular cup socket as discussed previously.

Alternatively or additionally, it is preferred that the surface of the socket coincides with that of a sphere at the intersection of the surface of the socket with a plane. In these circumstances, it is also preferred that  $R_2$  be less than  $R_1$  and that the radius of the sphere with which the surface of the socket coincides at the intersection of the surface of the socket with the plane be equal to  $R_1$ . In this way, an annular contact ring may be formed between the socket and the head which traps lubricating fluid between the two towards the point of minimum radius of curvature.

Both of the above preferred conditions may be satisfied in a single socket by arranging for the surface of the socket to be a surface of revolution about the normal to the surface at the point of minimum radius of curvature.

#### Brief description of the drawings

The present invention will now be described by way of example with reference to figures 1 to 3 of the accompanying drawings in which:

Figure 1 illustrates a conventional sphere on sphere prosthetic hip joint;

Figure 2 illustrates a joint according to the invention where  $R_1$  is greater than  $R_2$ ;

Figure 3 illustrates a joint according to the present invention where  $R_1$  equals  $R_2$ ; and

Figure 4 illustrates a particular geometry of the acetabular cup.

Detailed description

Figure 1 illustrates a conventional sphere on sphere prosthetic hip joint. The joint consists of an acetabular cup 10 and a spherical head 12 of a femoral component. The cup 10 includes a socket with a spherical concave surface 14 and the surface of the spherical head 12 is referenced 16. In the example illustrated, the radius  $R_1$  of the surface 16 is 9.8mm and the radius  $R_2$  of the surface 14 is 10mm, giving a difference of 0.2mm. This difference affords a clearance 20 between the two components of the joint and lubricating fluid is able to penetrate between the two within this clearance.

When the joint is placed under load, initial contact between the two surfaces 14, 16 occurs at a point 18. As the load is increased, surface deformation will cause the contact area to spread until the elastic restoring forces are equal to the applied load.

Because the predominant movement of the natural hip joint is one of rotation about the femoral head, the two radii  $R_1$  and  $R_2$  are selected to be close to one another, thereby reducing to a minimum the amount of play in the joint. As a result, the squeeze film lubrication performance of this joint is relatively poor.

Figure 2 illustrates an embodiment of the present invention in which  $R_1$  is greater than  $R_2$ . The joint consists of an acetabular cup 10 and the spherical head 12 of a femoral component. The surface of the spherical head is referenced 16. In this case, the surface 14 of the socket in the acetabular cup 10 is defined by an "alpharabola". The use of the alpharabola as the geometry of the socket allows the rate of change of the curvature of the surface to be varied continuously over the surface and this rate of change can be determined with a single parameter  $\alpha$ , once the desired minimum curvature is known. This allows the position and size of the contact area on the head 12 and cup 10 to be varied, permitting pools of lubricating fluid 22 to be trapped in the contact to assist lubrication. In addition, the need for a

radial clearance between the head 12 and the cup 10 is avoided.

The alparabola geometry is described by:

5

$$\alpha x^2 + y^2 + z^2 = 2R_2x$$

$$0 < \alpha < 1$$

10        where:         $R_2$  is the desired minimum radius of curvature;

$x$  is a Cartesian co-ordinate representing  
                 distance from the point of minimum radius of  
                 curvature along the normal to the surface at  
15                   that point; and

$y$  and  $z$  are the remaining Cartesian co-  
                 ordinates.

20 All these geometries are symmetrical about the  $x$  axis, ie.  
about the normal to the surface at the point of minimum radius  
of curvature, and this ensures that the alparabola surfaces  
are surfaces of revolution about the  $x$  axis.

25 In figure 2,  $R_2$  is 10mm and the parameter  $\alpha$  is selected to be  
0.5. The radius  $R_1$  of the head 12 is 10.5mm. As can be seen,  
a pool of fluid 22 is trapped at the pole of the alparabola  
and there is an annular contact ring 24 between the two  
surfaces 14, 16 which serves to trap the fluid. In addition,  
30 the decreasing radius of curvature of the surface 14 of the  
cup 10 as one approaches the rim ensures that the two surfaces  
14, 16 define a relatively large clearance 20 at the rim of  
the cup. This facilitates the ingress of lubricating fluid.

35 Figure 3 illustrates a joint according to the invention in  
which  $R_1$  is equal to  $R_2$  at 10mm. Again, the parameter  $\alpha$  is  
selected to be 0.5. As can be seen, there is again a  
relatively large clearance 20 between the two surfaces 14, 16  
towards the rim of the cup, but in place of an annular contact

ring 24, there is an enlarged contact area 26. Again, this contributes to more effective squeeze film lubrication and less wear on the two components. The reduction in wear is important, since it in turn reduces the amount of debris in  
5 the joint, which debris can cause unwanted reaction in the surrounding tissue.

The parameter  $\alpha$  can be selected according to the circumstances, but is necessarily less than unity. Usually,  
10  $\alpha$  will be greater than 0 and preferably lies between 0.5 and 0.9. Values of  $\alpha$  close to unity will in general be selected for metal on metal or ceramic components. Intermediate values will be chosen for polyethylene cups and lower values for cushion form bearings. The difference  $R_1 - R_2$  will normally  
15 be selected to lie between 0 and 1mm.

As can be seen from figure 4, the axis of symmetry of the alphasphere need not coincide with the polar axis of the cup, ie. need not be normal to the rim 28 of the cup 10. The point  
20 of minimum radius of curvature, referenced 30 will be positioned so that the normal to the surface at that point coincides with the direction at which load on the joint will predominantly be applied.



CLAIMS

1. An acetabular cup having a concave bearing socket adapted to receive the head of the femoral component of a hip prosthesis, in which the radius of curvature of the surface of the socket continuously and monotonically decreases from the lip of the socket to a minimum  $R_2$  at a point within the socket.
2. An acetabular cup according to claim 1 in which the surface of the socket approximates that of a sphere at the said point.
3. An acetabular cup according to claim 1 in which the surface of the socket approximates that of a sphere at the intersection of the surface of the socket with a plane.
4. An acetabular cup according to claim 2 or claim 3 in which the surface of the socket is a surface of revolution about the normal to the surface at the said point of minimum radius of curvature.
5. An acetabular cup according to claim 4 in which the surface of revolution is defined by the following relationship:

$$\alpha x^2 + y^2 + z^2 = 2R_2x$$

$$0 < \alpha < 1$$

where:  $x$  is a Cartesian coordinate representing distance from the said point along the said normal; and

$y$  and  $z$  are the remaining Cartesian coordinates.

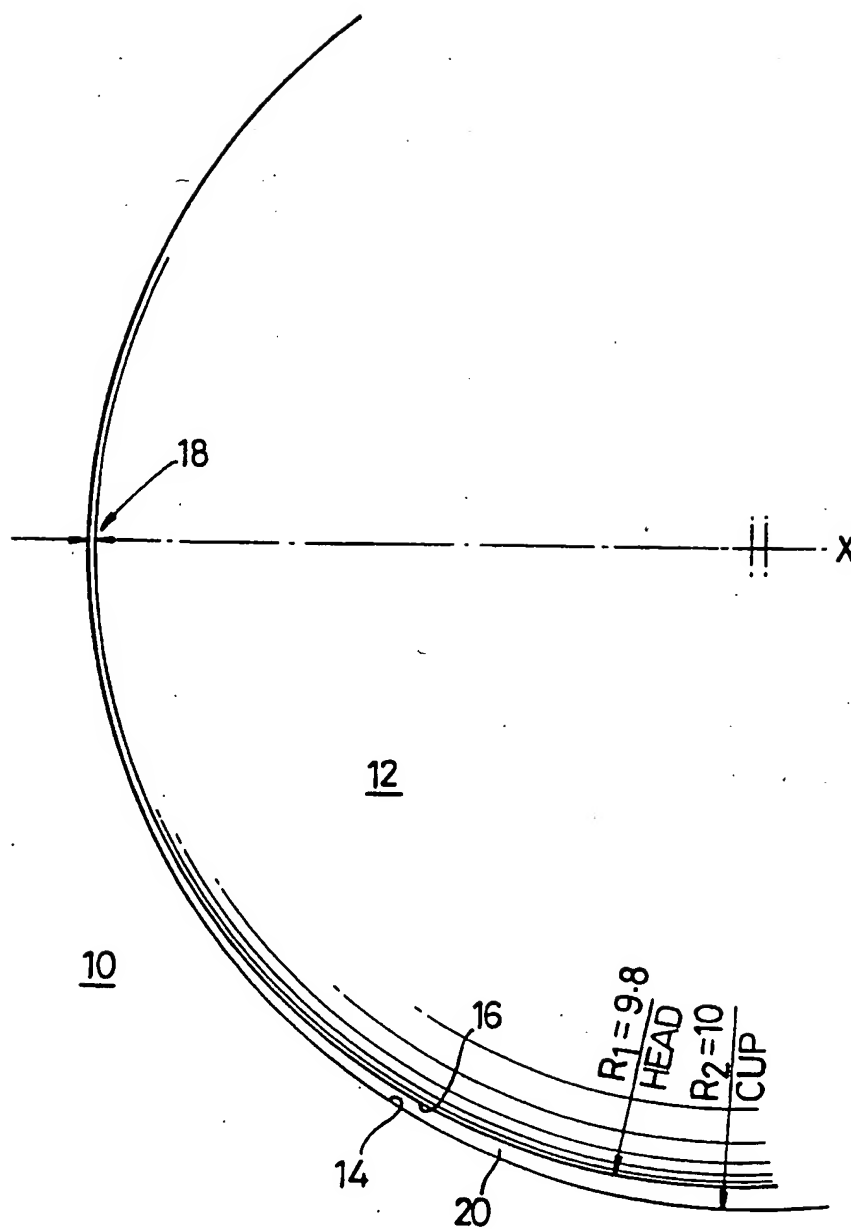
6. An acetabular cup according to claim 5 in which:

$$0.5 \leq \alpha \leq 0.9.$$

- 5 7. A hip prosthesis comprising an acetabular cup according to any preceding claim and a femoral component having a substantially spherical head, the concave bearing socket being adapted to receive the head of the femoral component, in which  $R_2$  is no greater than the radius of the spherical head of the femoral component  $R_1$ .  
10
8. A hip prosthesis according to claim 7 in which  $R_2$  is equal to  $R_1$  and the surface of the socket approximates that of a sphere of radius  $R_1$  at the said point.  
15
9. A hip prosthesis according to claim 7 in which  $R_2$  is less than  $R_1$  and the surface of the socket approximates that of a sphere of radius  $R_1$  at the intersection of the surface of the socket with a plane.  
20
10. A hip prosthesis according to claim 9 in which:

$$0 \leq R_1 - R_2 \leq 1\text{mm}.$$

1/4



SPHERE ON SPHERE

Fig.1

SUBSTITUTE SHEET (RULE 26)

2/4

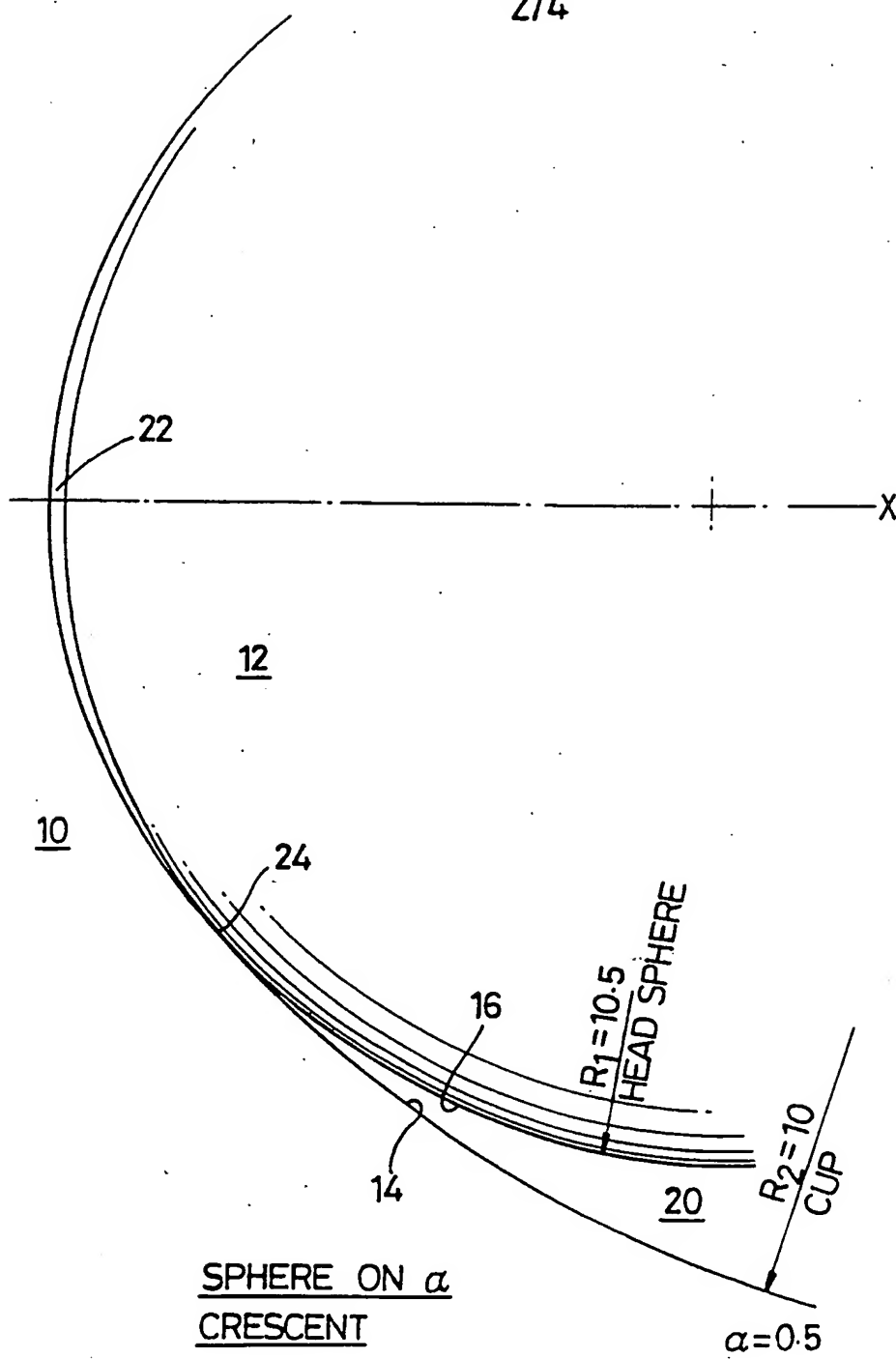


Fig. 2

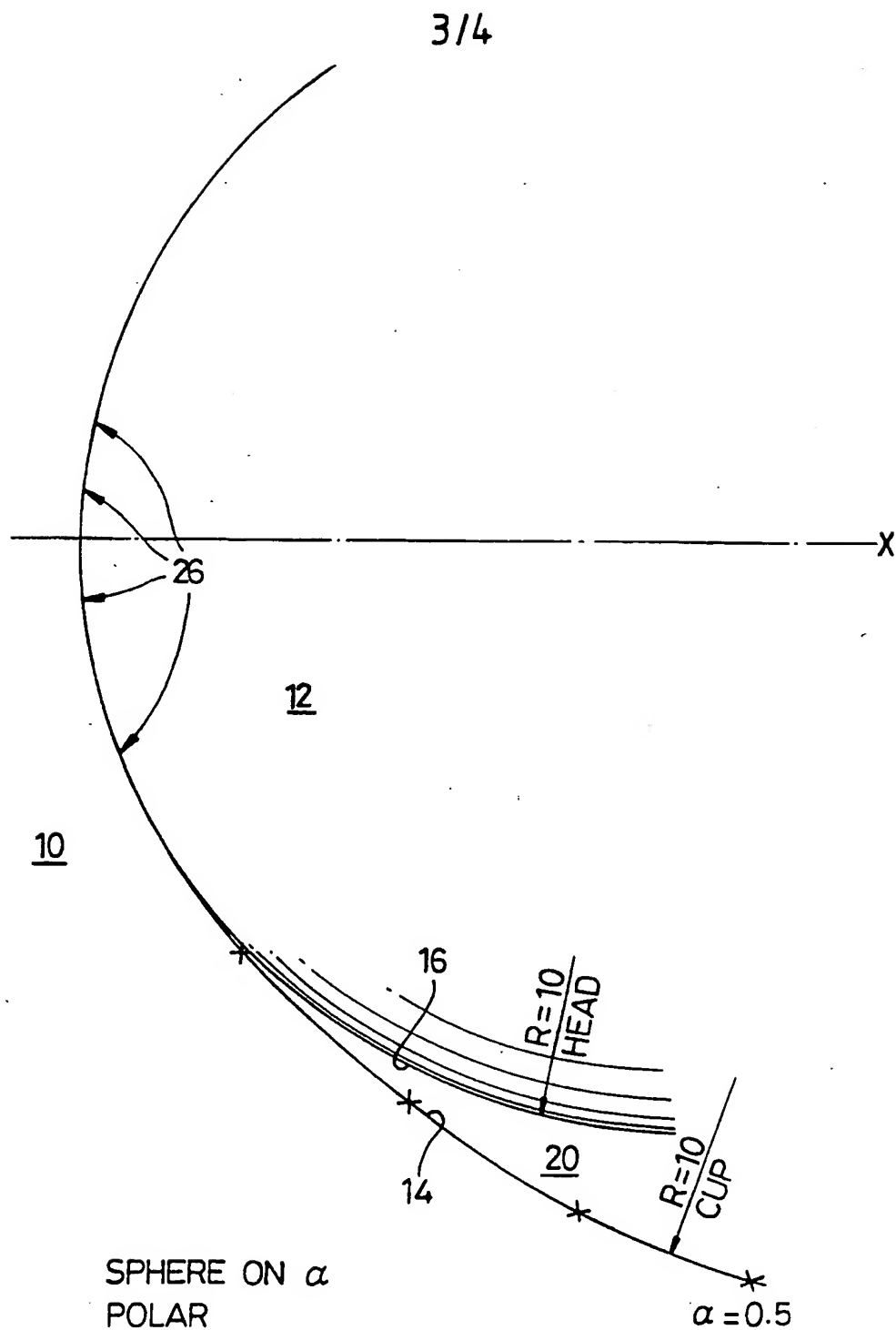


Fig. 3

SUBSTITUTE SHEET (RULE 26)

4/4

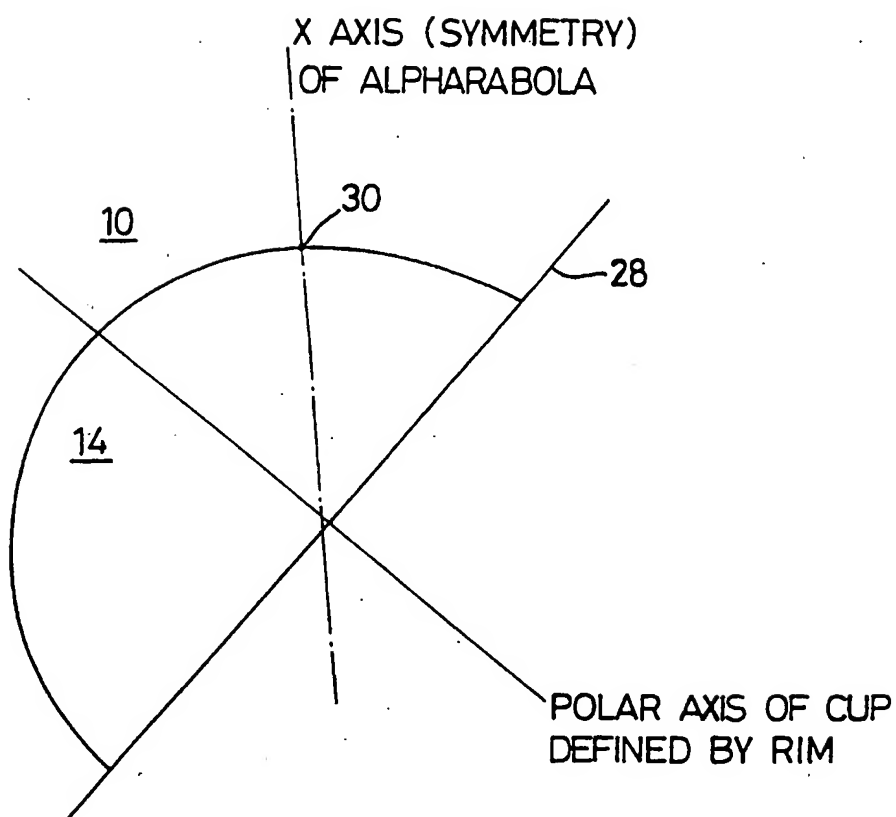


Fig. 4

# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/GB 95/00403

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 A61F2/34

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 A61F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	EP,A,0 302 850 (MENSCHIK) 8 February 1989 see the whole document ---	1-4 7
A	EP,A,0 226 762 (GEBRÜDER SULZER) 1 July 1987 see abstract; claim 1; figure ---	1-4,7
A	DE,A,38 40 468 (LIEKE) 7 June 1990 see column 1, line 45 - line 58; claim 2; figures ---	1
A	DE,A,36 30 276 (FELMET) 17 March 1988 see column 7, line 53 - column 8, line 10 ---	1
A	DE,A,27 42 464 (PFAUDLER-WERKE) 22 March 1979 ---	
	-/--	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

### \* Special categories of cited documents :

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
- \*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

\*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

\*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

\*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

\*&\* document member of the same patent family

Date of the actual completion of the international search

21 July 1995

Date of mailing of the international search report

03.08.95

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax (+31-70) 340-3016

Authorized officer

Klein, C

# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/GB 95/00403

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	FR,A,2 134 170 (BENOIST GIRARD) 8 December 1972 ---	
A	FR,A,2 315 903 (SULZER FRÈRES) 28 January 1977 ---	
A	WO,A,86 01394 (MATHYS) 13 March 1986 ---	
A	FR,A,2 413 078 (SEROLE) 27 July 1979 -----	



# INTERNATIONAL SEARCH REPORT

Intern: ul Application No

PCT/GB 95/00403

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A-0302850	08-02-89	AT-A- 386948 CA-A- 1296837 DE-A- 3877457 JP-A- 1070040 US-A- 4911723	10-11-88 10-03-92 25-02-93 15-03-89 27-03-90
EP-A-0226762	01-07-87	CH-A- 667988 US-A- 4784662	30-11-88 15-11-88
DE-A-3840468	07-06-90	NONE	
DE-A-3630276	17-03-88	NONE	
DE-A-2742464	22-03-79	NONE	
FR-A-2134170	08-12-72	BE-A- 783809	18-09-72
FR-A-2315903	28-01-77	CH-A- 593054 AT-B- 341653 BE-A- 843112 CA-A- 1053851 DE-A- 2527865 GB-A- 1499463 JP-A- 52002092 NL-A- 7606233 SE-A- 7606740 US-A- 4031570	15-11-77 27-02-78 20-12-76 08-05-79 23-12-76 01-02-78 08-01-77 21-12-76 19-12-76 28-06-77
WO-A-8601394	13-03-86	CH-A- 663895 EP-A,B 0193538 US-A- 4840631	29-01-88 10-09-86 20-06-89
FR-A-2413078	27-07-79	NONE	